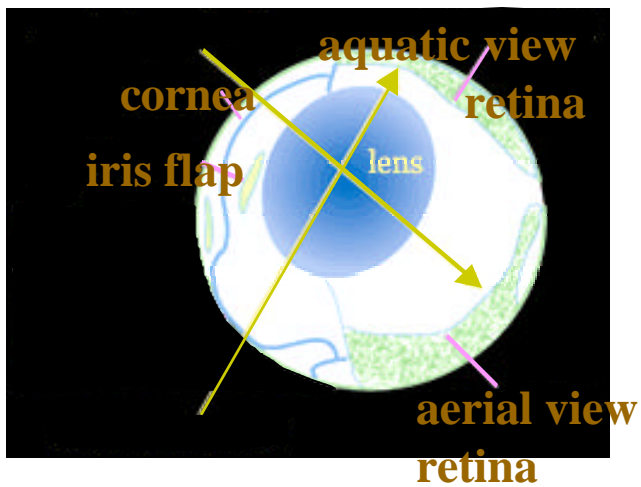
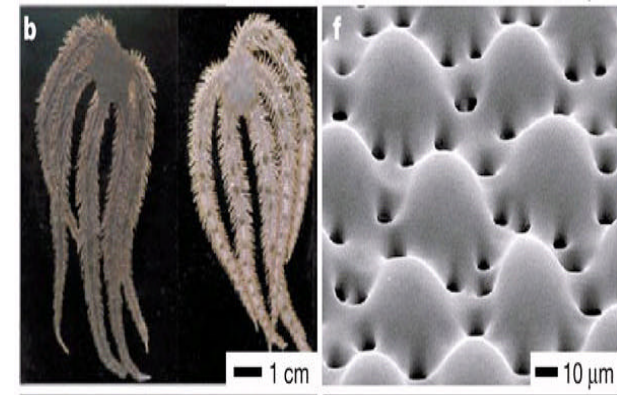
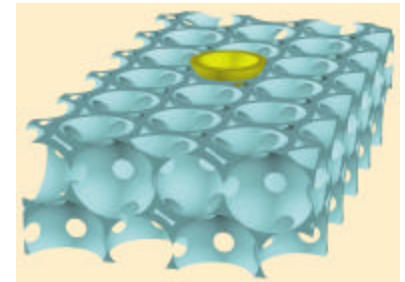
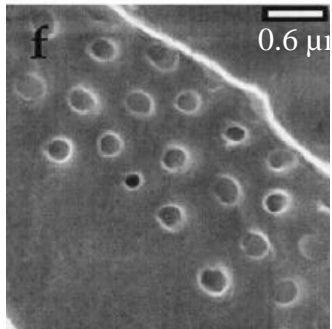
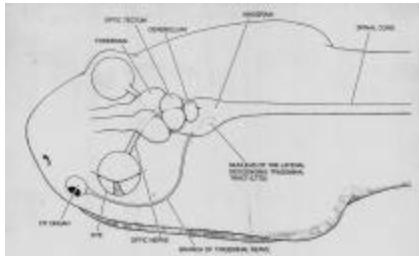
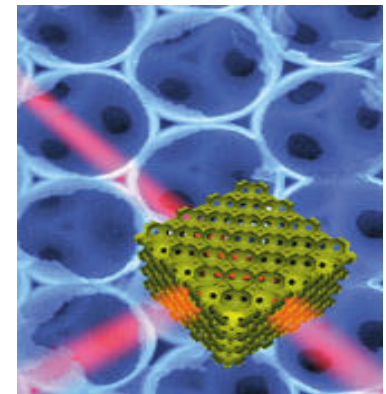


Synthetic Approaches to Bio-Optic Systems

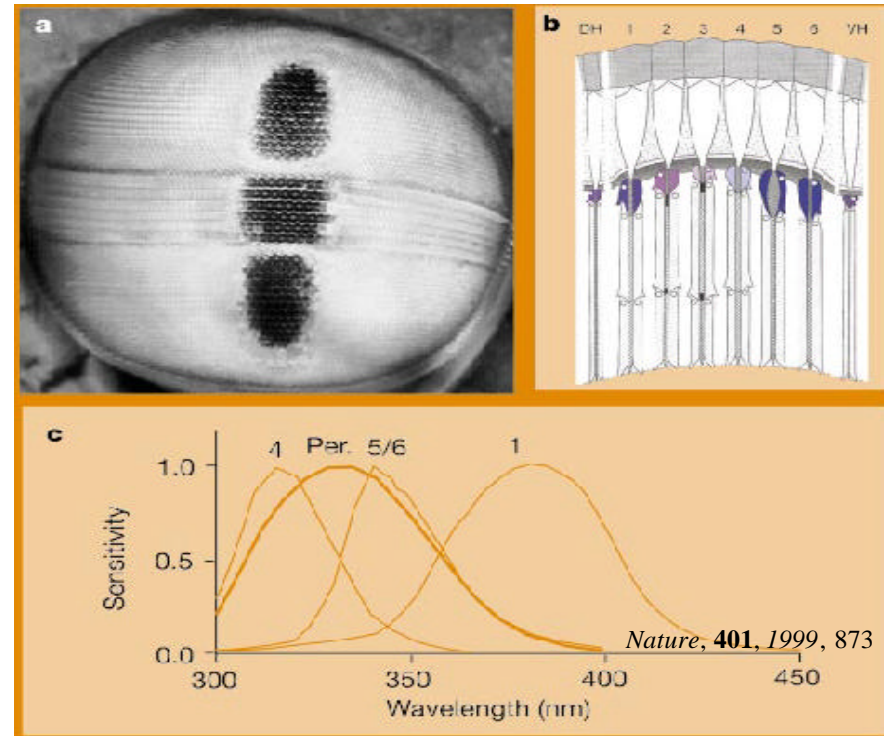


Leonard J. Buckley
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- UV vision
- Several narrow-band photoreceptors
- Lower sensitivity but higher color discrimination



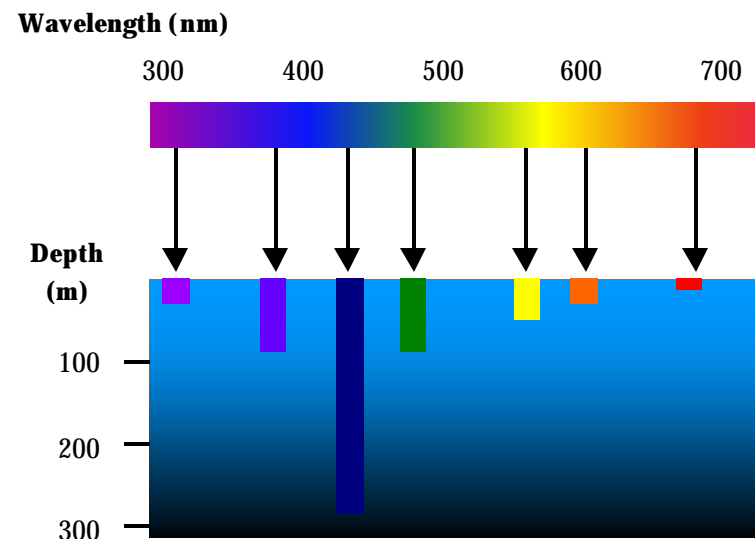
Multi-band Sensitivity

- Prey and Predator Recognition
- UV scattering provides better contrast

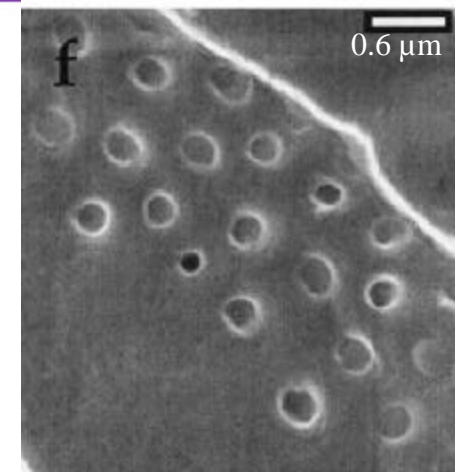
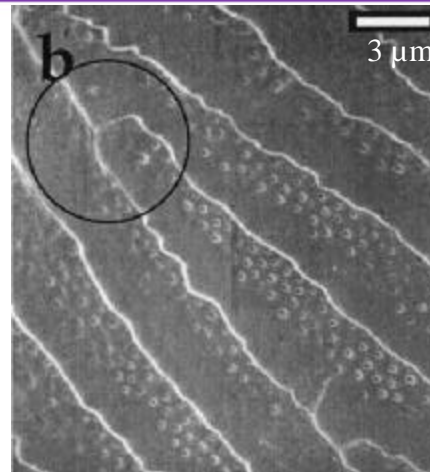
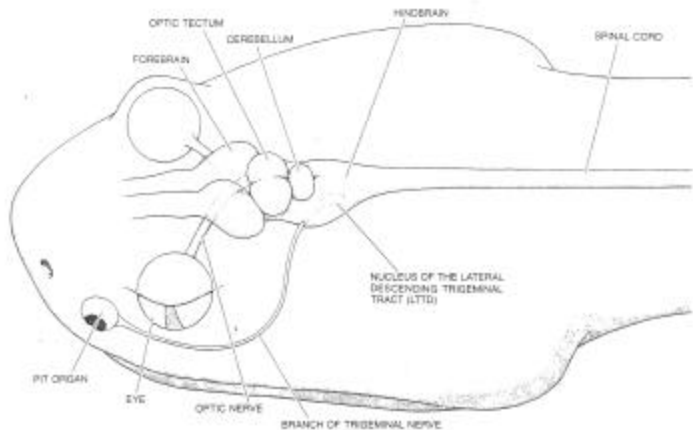


UV

B&W

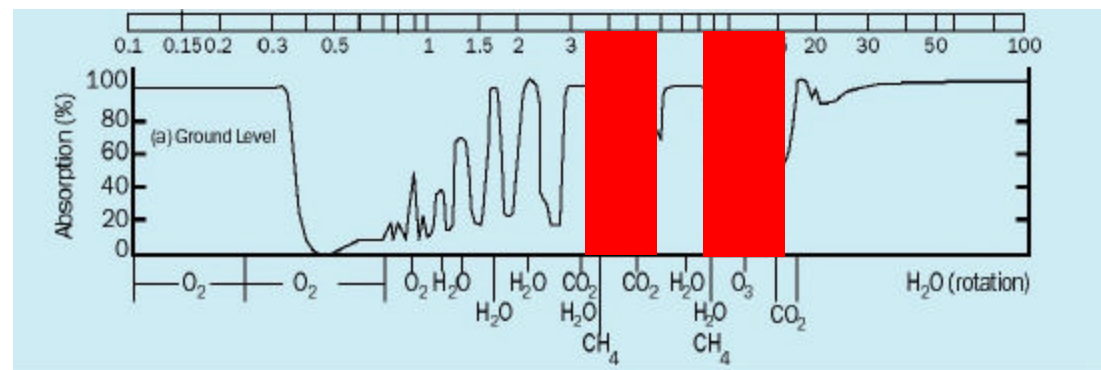
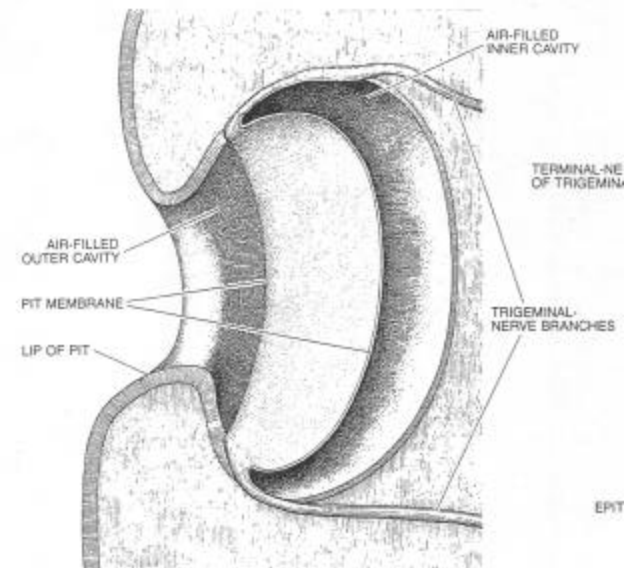


Snake Pit Organ

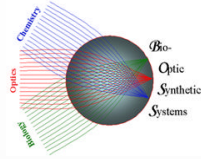


- 0.02 °C sensitivity
- Suspended from body
- Covered by unique scale that only transmits IR 3-5 and 8-12 μm

J. Struct. Biol. **126**, 1999, 105



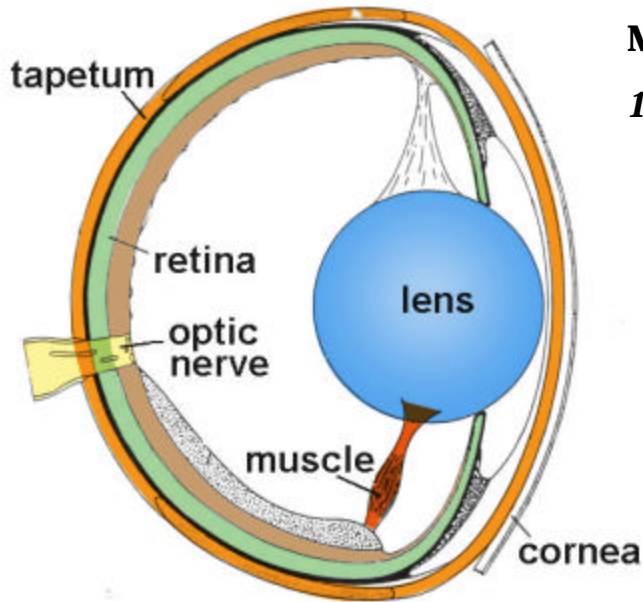
Brittlestars Microlenses



- *Calcite microlenses with the function of a compound eye**
- *No photosensory organs yet can “detect shadows”**
- *Sensitivity to light correlates with structure**
- *Calcite has different refractive indices for light polarized in different directions**

*Useful for improved:
Fill Factor
Cold Shield Efficiency*

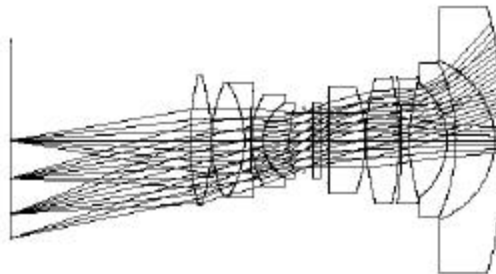
Spherical Aberration



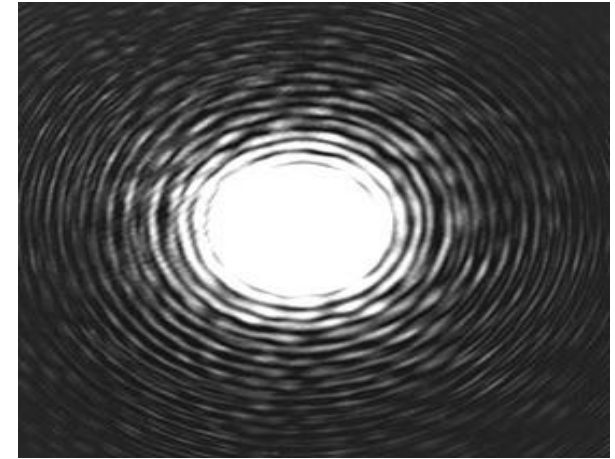
Man-made Fisheye Lens
1000x Larger in Volume



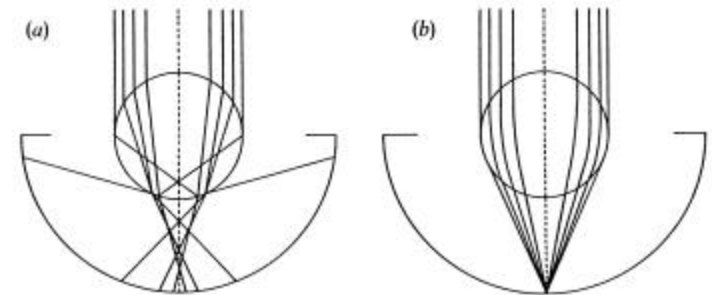
Graded
Index of Refraction
 $\Delta n = 0.22$ or greater



Complicated focusing in Man-made system



- Peripheral rays are over-focused
- Results in poor image quality

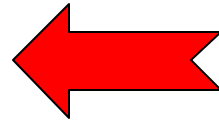


Standard Lens

Fish Eye Lens (GRIN)

(Spherical aberration is a problem in all optical systems based on spherical interfaces)

**Synthetic
Bio-Inspired Optics**



Beyond

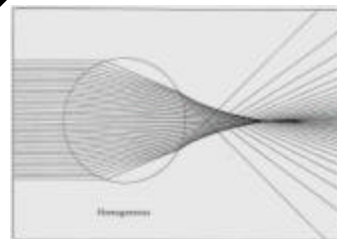
- Variable Index Lens
- Dynamic Field of View
- Multifunctional Optics
- Fewer Components



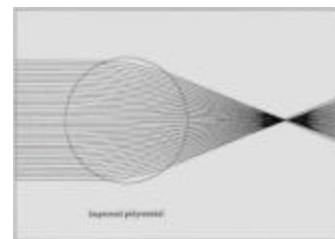
**Multi-layer Structure
in Human lens**

Today

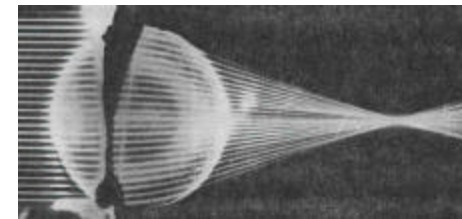
- Fixed Index Lens
- Limited Field of View
- Single Function Optics
- Many Components



Standard Lens

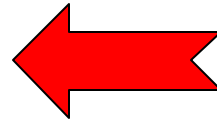


Graded Index Lens



Octopus Lens

**Synthetic
Bio-Inspired Optics**



Beyond

- Variable Index Lens
- Dynamic Field of View
- Multifunctional Optics
- Fewer Components

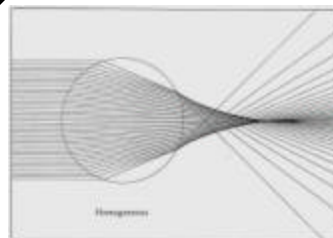
**Dynamic Control of the Refractive Index
Wavelength Variable Reflectance
Hierarchical Material Structure**



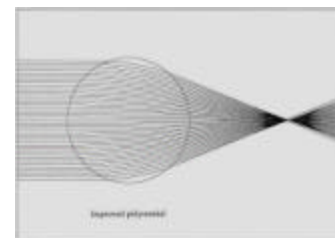
**Multi-layer Structure
in Human lens**

Today

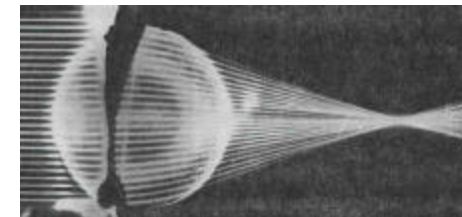
- Fixed Index Lens
- Limited Field of View
- Single Function Optics
- Many Components



Standard Lens

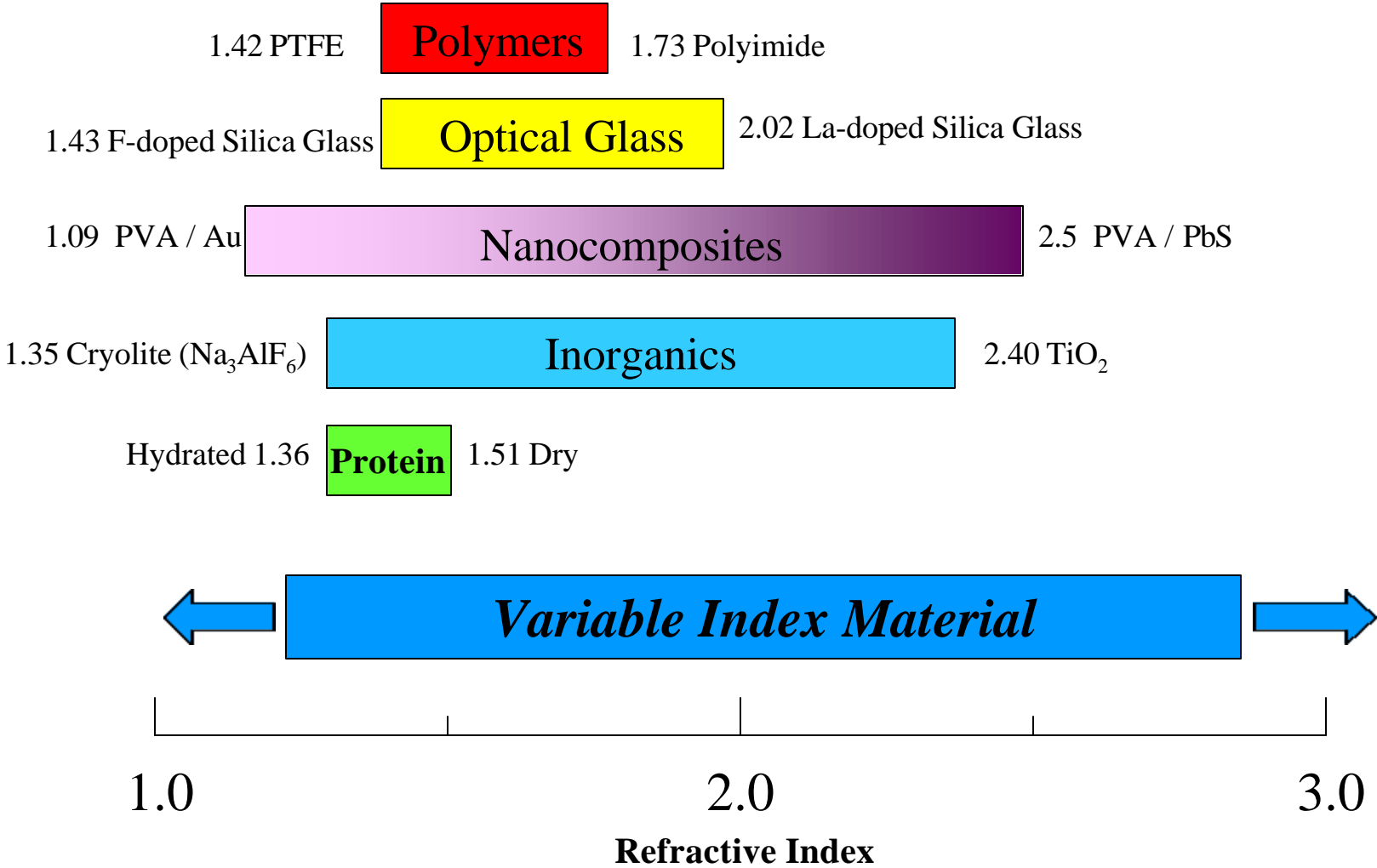


Graded Index Lens

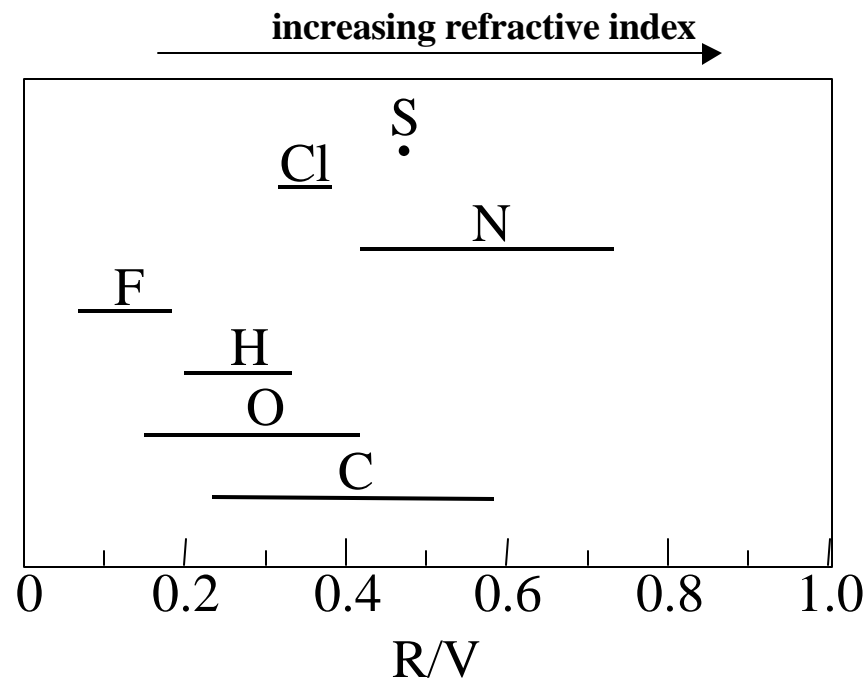


Octopus Lens

Refractive Index



Dynamic Control over a wide range of refractive indices



Role of Morphology

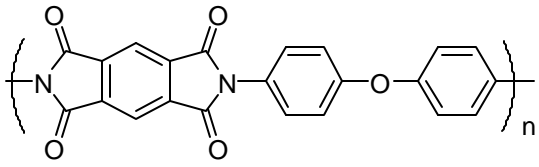
Semi-crystalline PTFE = 1.42 (@ 1 GHz)
Amorphous PTFE = 1.36 (@ 1 GHz)
Completely Amorphous PTFE = 1.29 (calculated)

Lorenz-Lorentz Equation

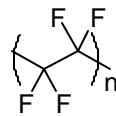
$$\frac{n^2-1}{n^2+2} = \frac{R}{V}$$

R = Molar Refraction
 V = Molecular Volume
 (Density/Molecular Weight)

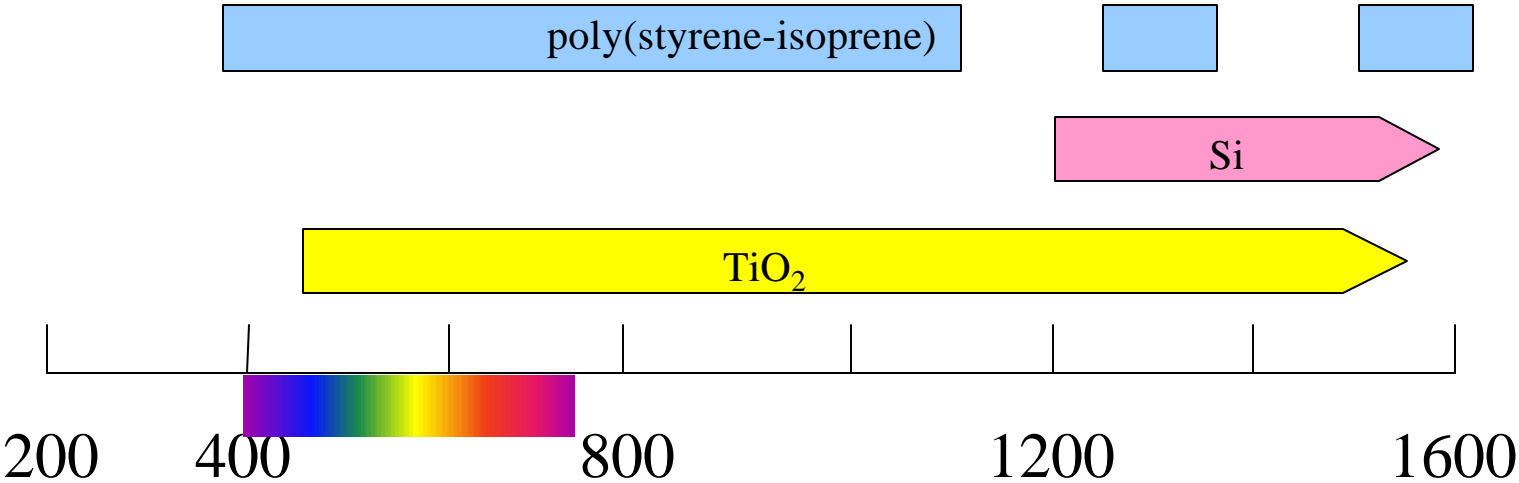
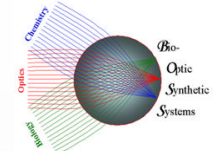
Polyimide n=1.7



Polytetrafluoroethylene n=1.42

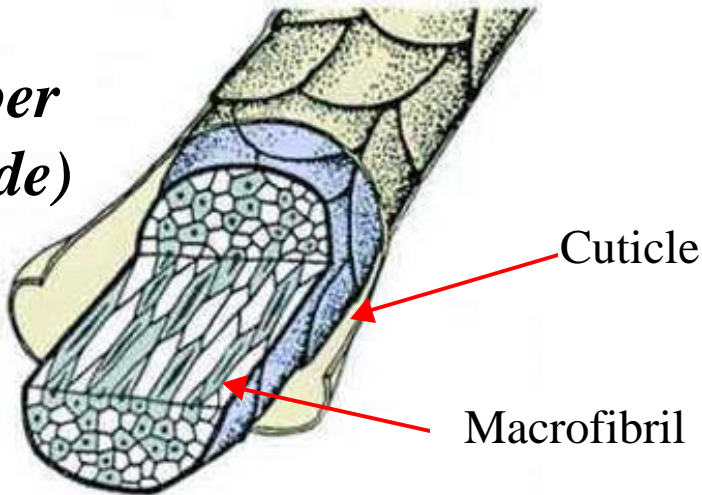


Spectral Window





*Wool Fiber
(polyamide)*

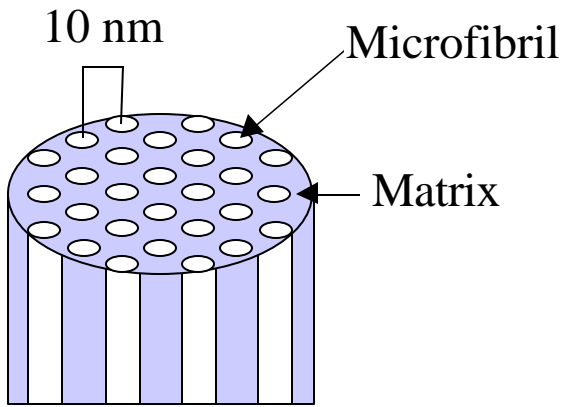


- Intermediate fibers embedded in matrix
- Macrofibrils bundled together
- Cuticle tie macrofibrils together

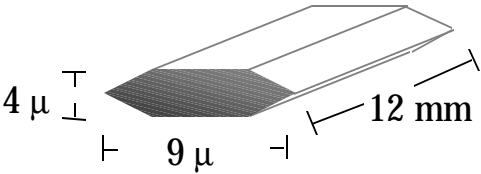
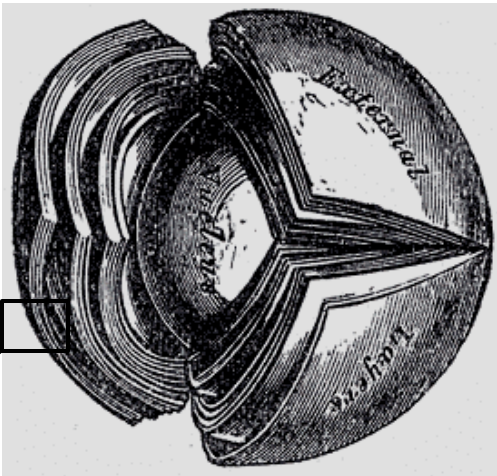
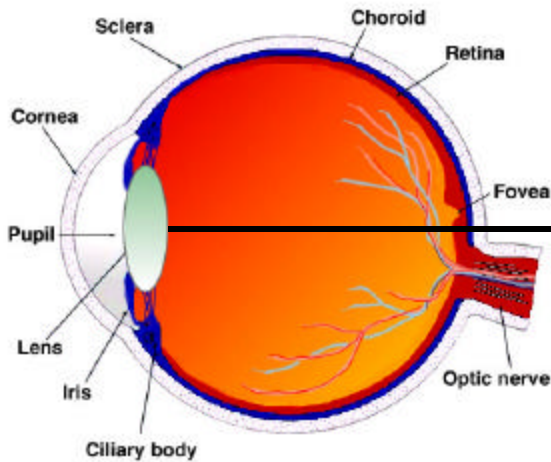
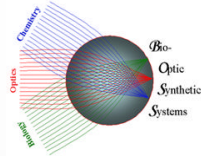
“Nylon” Fiber (polyamide)

*Can secondary bonding forces
be used to enhance morphological
complexity?*

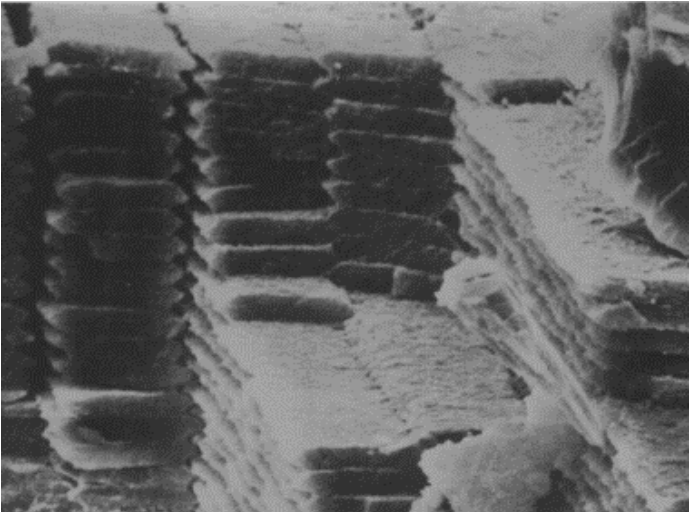
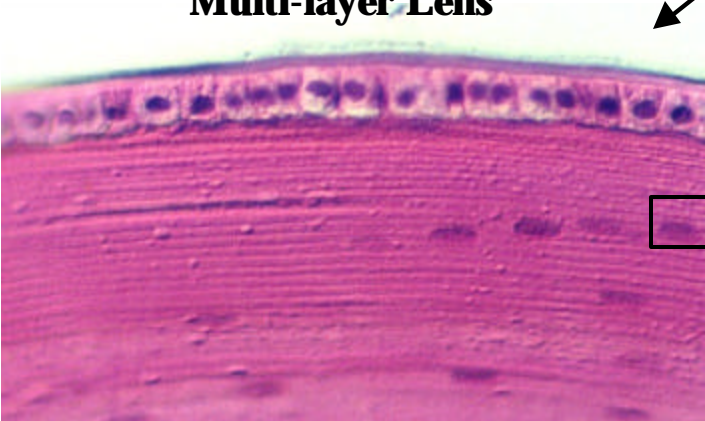
Can the process proceed at a facile rate?



Role of Structure



Multi-layer Lens



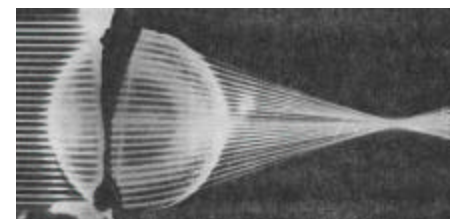
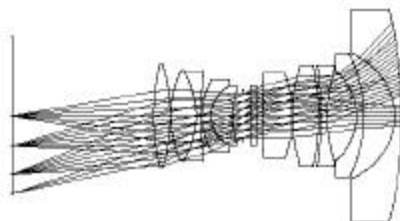
22,000 layers for human lens

Polyelectrolyte deposition for synthetic lens

**Fixed Index Lens
Limited/Fixed FOV
Many Parts**

Today

***Dynamic Control of Refractive Index
Wavelength Variable Reflectance
Hierarchical Structure***



**Controllable Index Lens
Dynamic FOV
Simplified Optics**

FY-06

Technical Milestones:

Phase I

1. 3Q FY03 Develop a dynamically variable lens compound that exhibits a full point (1.0) reversible change in the index of refraction in the visible-NIR with 95% or better transparency.
2. 1Q FY04 Demonstrate the use of self-assembly processes to synthetically reproduce materials with a variable reflection in the VIS to near-IR that performs as a wavelength variable bandpass filter.

Phase II

1. 4Q FY06 Demonstrate a re-configurable optical system that includes a multifunctional lens, a wavelength variable reflective packaging system, and an artificial retina.

Meeting Objectives

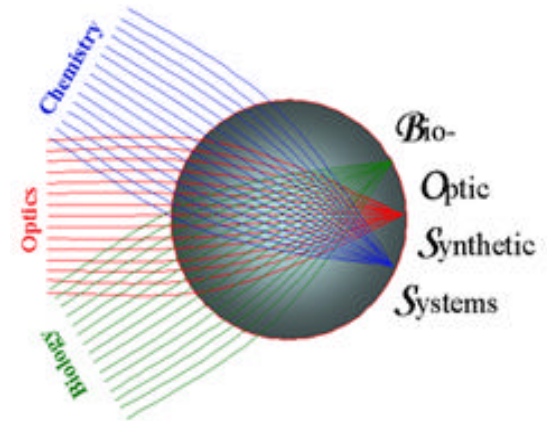
- **Introduce Concept**
- **Facilitate Teaming**
- **Clarify Program Details**

FAQ's

- * **Spectral band of interest**
- * **Response time**
- * **Size (necessary to demonstrate proof of concept)**
- * **Index range (goal=1.0)**

Programmatics

- * **BAA is open till AUG, 2002 (60 day/7day)**
- * **Anticipated level of effort**



Idea:

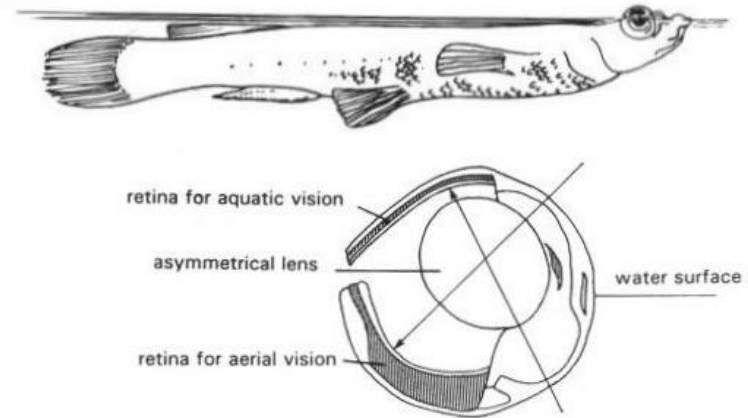
***To understand and synthetically reproduce the components of biological vision systems that would greatly reduce the need for multiple sets of optics**

Technical Challenges

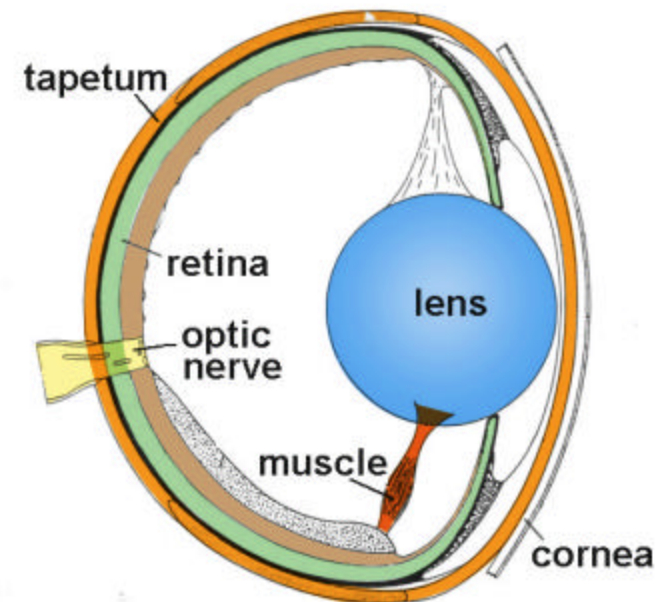
- Materials with a **dynamic index of refraction**
- Develop a **variable FOV lens**
- Synthetic pathways to **extreme materials**
- Develop Bio-inspired optics

Impact

Multifunctional molecular optics that are bio-inspired and greatly simplify the optics on a variety of sensor systems



Four-eyed Fish



Fish Eye